MUNICIPAL ENERGY SAVINGS FOR THE CITY OF WORTHINGTON

Environment, Economy, Development, and Sustainability Capstone Course Autumn 2016

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EXECUTIVE SUMMARY

The main research goals for this project were to develop a plan for the City of Worthington to reduce the energy usage of their municipal buildings. This was accomplished through the collection of utility data for the buildings, as well as onsite walkthroughs, and studies of similar energy efficiency projects. Through the onsite walkthroughs performed by our team we determined the target areas for improvement. These target areas consisted of: outdated and drafty windows, inefficient lighting fixtures, outdated and inefficient HVAC systems, deteriorating roofing, and an abundance of impermeable pavement. Our recommendations were then ranked, according to cost effectiveness, ease of implementation, and complexity. Our main findings showed that insulating the city building's windows would be the least expensive and most cost effective way to save energy and offer the shortest payback period for the investment. Our highest capital cost and logistically complicated recommendation was improving roofing, and implementation of more permeable pavements around the municipal buildings. While the city is constrained by a tight budget, plans are currently being created to address roofing, and we recommend the implementation of permeable surfaces could be added to those plans to make progress in that area, because renovations to the buildings will already be occurring. The implementation of our team's recommendations will cut energy costs and subsequently, in the long run, ease the strain on each building's individual budgets, allowing them to improve the services that they provide to the community of Worthington, Ohio.

INTRODUCTION

This project is the result of a plan to audit the utility usage of each municipal building in the City of Worthington, Ohio. In response to the Request for Proposals from the City of Worthington, our team was tasked with addressing the city's sustainability goals pertaining to city energy savings. The ultimate goal of our project is to reduce the energy usage in the city's six municipal buildings. These buildings include: the police station, the fire department, city hall, the community center, the service & engineering department, and the planning & building department. For the project our focus was on energy and water usage, involving three utilities of: Water & Sewage, Gas, and Electric. Our plan for addressing the energy and water usage of these municipal buildings was comprised of three main steps. First, the bills for these utilities were acquired and entered into a spreadsheet for basic data analysis. Next, onsite walkthroughs of each building were performed in order to better assess the target areas that could be improved in each building. Finally, the utility data analysis was coupled with the onsite walkthroughs to develop recommendations for each building, including cost-benefit analysis data from comparable energy efficiency projects in other cities. The findings were then ranked based on ease of implementation for the city, in terms of man power, capital expenditures, cost effectiveness and complexity. This resulted in several "low hanging fruit" recommendations that could be accomplished relatively easily, and with substantial resultant cost savings, such as adding window insulation, and switching to LED lighting.

RESEARCH OBJECTIVES

METHODS

In order to identify environmental challenges of the city of Worthington and reduce its energy costs, we thought it was necessary to first review the last 12 months of the utility bills for each of the buildings. We collected this data in order to have a better understanding of the energy trends and usage of each building type and utility type. With the generous help from Molly Roberts, Scott Bartter, Robyn Stewart and Vickie Greene, we were give copies of the utility bills (water and sewage, gas, and electric) for each of the buildings of focus: Community Center, Planning and Building, Service and Engineering, Police Department, Fire Department and City Hall. Although analyzing data is vital, it is only the first step in cost savings. We conducted a walk through at each of the buildings with exception of the police department. These visitations were conducted in order to provide a visual sense of the conditions of each of the buildings we are studying. We visited each of these city buildings and spoke with staff members to get a hands on perspective of the operations of each and how that plays into how much energy is being produced and why. Chuck Sgandurra is Worthington's Building Maintenance Supervisor who was very helpful in allowing us to get a better understanding of the lighting, the appliances, challenges, and other specific information needed. The information we gathered from these tours helped shape our recommendations we formulated. The final stage in our project was to research cost-benefit analyses and case studies showing the potential cost saving benefits that can occur with the implementation of each recommendation.

DATA COLLECTION & ANALYSIS

The utility bills were entered into an excel spreadsheet specifying building type, billing period and date, energy usage in the respective unit, and total amount paid. The information we looked at was the trends in energy usage per month over the 12-month period and the daily energy usage in relation to the square footage and how that compares with other buildings' rates. We felt that this was an effective way to see how energy usage and costs measure individually based on each building, and in order to compare the costs without the size of the building being a variable.

We have included two graphs of the gas and electric depicting the annual costs in relation to the square footage of the building. For water, we did not apply square footage as it did not seem necessary. This was done in addition to comparing the costs and energy of each building. The purpose of this is to measure these costs and usages without the size of the building being an influence to price because the buildings all vary drastically in size. It is understood that using cubic feet as a unit would have been produced more well-rounded results but we had to work with the information given to us at the time, which were dimensions in square footage. Figures 1-3 show the relationships between the usage of each building and each other. Figures 4-6 show the costs of each utility for each building per square footage. For the water portion in Figure 2, the community center's pool was taken out of the data range due to its high values. This was done to see a better comparison of the other buildings' water usage without an outlier present. The highest consumer of electricity of the six buildings is the community center

(Figure 3) but this is an expected outcome due to its functions and hours of operation. The second highest consumer of electricity was the police station both individually and costs per square footage (figure 3 and 6). Comparing the usage versus costs, even though the Service and Engineering building has had the highest usage of gas over the past year (Figure 1), it is the fire department that has the highest cost of gas per square foot (Figure 6). This is interesting because the Service and Engineering building is half of the size of the fire department. This could be because of the large empty spaces in a warehouse like setting that are expensive to heat especially in the winter time. This could be an insulation opportunity for this specific building and needs to be further looked into. In regards to the size of the building not being an influence, the fire department has the highest gas usage and costs per day (Figure 4) due their hours of operation and specific needs. Excluding the part of the community center where the pool resides, out of all of the buildings City Hall had the highest cost per day for water per square foot. This is especially alarming due to their hours of operation shorter than some of the other buildings and their functions not requiring as much water usage, such as fire department and police department. This is definitely an opportunity for this building to look at.

RESEARCH FINDINGS

The goal of our research was to identify key energy saving recommendations for each City of Worthington building we were asked to evaluate. These findings were the result of data analysis, research into the budget for the City of Worthington, walkthroughs with the building managers, and using comparable examples to evaluate each recommendation. Given the lack of flexibility in the budget for the City, our recommendations are not simply those with the highest energy savings. Our findings were prioritized based on likelihood of implementation based on all of our research. The first finding was that each building should invest in plastic window insulation kits for their windows, which would result in a 33 percent increase in insulation for the windows (Craven 2011). Our second finding was that each building would benefit greatly from retrofitting their lights to LEDs, as well as adding motion sensors, where able. This upgrade could see an extremely quick payback period of two years in some cases, but is also more expensive on the scale suggested (Green Age 2016). Our third recommendation is to upgrade the windows with either new replacements or Hi-R retrofitted panels. These Hi-R panels are cheaper and easier to install, and saved a federal building in Utah 41 percent on their winter energy use, which is estimated payback of nine years (GSA 2013). Our next finding was that the HVAC systems in many of the buildings, (specifically the Planning & Building, Service & Engineering, and City Hall) are far past their expected life cycle. Given the expense of this upgrade, it is our recommendation that Worthington continues their current strategy of replacing HVAC systems once entirely broken, however, when this occurs, they should upgrade to the highest efficiency models to cut energy usage in the future. Our final recommendation was to improve the roofing, as is planned for the Community Center and Fire Department. This recommendation was evaluated given the fact that it is planned out of necessity already, though the energy benefits, if done correctly, will still be beneficial.

Research Barriers

In the process of arriving to the above results, we also encountered some barriers. Given that Worthington has largely exhausted their budget for the next few years, it was difficult to prioritize recommendations for energy savings. Worthington built most of the city buildings we evaluated in the 1980s, and some have not been substantially upgraded since. Further, there was no fund created in the past to be required for future use. Also, with the 2008-09 recession, Worthington began delaying many of the upgrades that would've otherwise been completed years ago. Still in catch up mode from this, Worthington does not currently have large sums to invest in upgrades. Given that energy saving upgrades is not a necessity (unless required, such as new HVACs), our recommendations had to be realistic given the current financial situation of the city. In the end, we feel we overcame this barrier and were able to produce recommendations that are realistic for the City of Worthington to implement.

RECOMMENDATIONS

Based on the above findings, our team has amassed a set of recommendations that we believe will be most likely to benefit the City of Worthington in an economic, yet sustainable, manner. These recommendations include: plastic insulation for especially drafty windows, adoption of motion-sensor LED lighting, upgrading windows and HVAC systems, investing in upgraded roofing, and transitioning of some paved surfaces to permeable pavement. Starting with the simplest and most straightforward recommendations, our group has decided to prioritize these proposals by ease of implementation. In addition, we have listed the buildings that would benefit from each respective proposal.

Recommendation #1: Installing Plastic Window Insulation Kits

Our first recommendation is to install plastic window insulation kits to the windows of all six buildings. These kits are a simple way to save energy through conduction heat lost, given that glass is not a very strong insulator. This is our highest priority recommendation because it has very low upfront cost, is easily installed by building occupants, can be applied to each building we evaluated, and will have a short payback period and the highest long term return on investment of all the recommendations. After our walkthroughs of the buildings, it was clear that heat loss through old windows was a primary concern. Given that the Planning and Building department is currently housed in the former police station, they have far more space than required and occupy an older building. Furthermore, other than a small set of windows in a walkway, which are double pane, all the windows in the building appeared to be single pane.

City Hall was another building of note when considering those which would benefit most from this recommendation. The building was constructed with wood-framed windows, many of which have had a temporary sealant added to prevent continued heat loss through deteriorating window frames. Though the fire department and Community Center have double pane windows throughout much of their space, they would still benefit from the insulation kits. Given that the Community Center has windows in every activity room and a substantial amount in their pool area, they would be able to reduce heat loss in the two areas they are most concerned with, while keeping the gyms and workout areas at the same cooler temperatures. The fire department office and dormitory spaces have windows throughout, and thus would also benefit from decreased heat loss in the winter by adding window insulation kits. Overall, window insulation kits have important advantages in that they can be implemented immediately, which of course leads to immediate energy cost reductions this winter, compared to last.

While the walkthroughs led to the realization that window insulation would be the highest priority recommendation, a study by the University of Nebraska supported this with the ability to calculate energy savings for each building. The R-value of each window is the degree to which it loses heat through conduction, and thus increasing the R-value will reduce heat loss (Boschetti 1984). The cheapest and easiest option for increasing R-value in the short-term is through the application of a glazing window cover to reduce convection loss. The addition of a plastic layer on the windows is similar to adding another window-pane, though the cost and implementation is far easier. Installing these window covers results in a 33 percent increase in insulation of the window (Craven 2011). Given that most of the buildings have original window fixtures, with no funds available immediately for improvement, this would be a cheap and short-term way to obtain the benefits of double and triple-pane windows. Applying this film to single pane windows would take the R-value from 0.9 to 2.0, while increasing double pane windows from 2.0 to 3.2 (Boschetti, 1984). While newer windows would result in much higher R-values (modern triple pane windows have R-value above seven (Craven, 2011)), the formula from Nebraska's study was a more realistic comparison given that many of the windows evaluated are also from the 80s.

To evaluate the monetary savings that Worthington would see, the formula provided by Boschetti was employed. The formula is 24*HDD*U value*square feet of glass. HDD, or Heating Degree Days, is a measure of heat required based on outside temperatures over a year. The HDD value of 4274 used in these calculations was taken from AEP Ohio's calculations for Columbus, Ohio in 2016 (AEPOhio.com, 2016). The U-value of a window is obtained through dividing 1 by the R-value of the window. Thus the energy loss through the current single-pane windows in the Planning and Building building was calculated as 24*4274*1.11*1=113,859.36 BTU of heat loss/square foot of glass/year. Based on a rate for electricity of $0.09 per kWh, it was calculated that each million BTU lost costs Worthington $26.30. Thus, through their current windows, Worthington is leaking $2.99/square foot of single-pane glass/year. This formula was then manipulated with the increased R-value of 1.5, which is a low estimate, after placing a window insulation glaze on these single-pane windows. The BTU loss with the window glaze would be reduced to 67,700.16, which would mean an energy loss of $1.78/square foot of single-pane glass/year. This represents a savings of $1.21/square foot/year. A 3M window insulator kit found on Amazon.com would be an investment of $0.18/square foot. Thus each window treated with this insulation kit would result in a net saving of $1.03 per square foot of glass per year. While this does not take into account time spent by employees to install the kits, this should be a minimal effort; if an employee with a wage of $25/hour applied only one kit (131 square feet) of insulation an hour the savings would still be $109.93 per kit. In summation, this is an incredibly easy way for each government building to save a large amount on their energy bills.

Recommendation #2: LED Lighting and Motion Sensors

Our next priority recommendation, one that our team believes can be implemented with ease, is to upgrade the noted buildings to LED lighting. This would be a drastic upgrade from the existing fluorescent, and in some cases, incandescent lightbulbs observed during the walkthroughs. In addition to this recommendation, we suggest that motion sensors also be installed in order to better regulate the cumulative amount of time that the lights stay on.

LED lighting carries an advantage over the other two lightbulb styles on a multitude of fronts. First and foremost, LED lighting uses significantly less energy than the other two lighting methods. It can be up to 5% more effective than the gaseous method utilized by fluorescent lighting, and up to 85% more effective than the filament method utilized by incandescent lighting (Layton 2008). The energy efficiency realized by LED lighting also manifests itself in another manner, total lifespan. LED lifespan varies depending on scenarios, but it is not uncommon for an LED to last 20,000 hours or longer. Some have even been reported to have a lifespan up to 50,000 hours (Layton 2008). This extensive lifespan more than compensates for the higher initial cost of purchasing LED lighting. Because LEDs are a form of solid state lighting (SSL), they radiate heat in a different manner than their predecessors. This heat must be dragged away from the heat source, and as such, LEDs are also safer than their predecessors in the sense that they will not burn someone at the touch (Energy Star 2016).

A good example of retrofitting to LED lighting comes from The Green Age, a London-based sustainable technology company who adopted LED lighting in their office headquarters. In their three meeting rooms, they swapped out nine fluorescent tubes with LED tubes and also installed a motion sensor in each room. They also implemented a regular maintenance service to clean the bulbs and fixtures in order to prolong lifespan. Immediately, the total wattage output from the three meeting rooms dropped by nearly half, from 351W to 180W (Green Age 2016). In addition, the overall time the bulbs were in use was also reduced by half, from 16 hours per day to eight. These measures helped to lower the overall annual energy cost for the meeting rooms to £78.84, an annual savings of £228. At £40 per LED tube, the nine new lights cost The Green Age £360. An additional £75 price for three motion sensors (£25 per unit) brings the total cost of meeting room renovation to £435 (Green Age 2016). With energy savings from the LED lights averaging £228 annually, it would take slightly less than two years for the upgrades to pay for themselves. Assuming a 30,000-hour lifespan and eight-hour usage per day, that's slightly greater than a 10-year lifespan. Considering the LEDs pay for themselves in the first 20% of their lifespan, they are worth the initial investment. Furthermore, as technological innovations advance, it is reasonable to believe that the price of LED lighting will continue to decline. Thus, the payback period may be even more rapid in the future, compared to the two years recognized currently by The Green Age.

As stated above, Worthington uses both incandescent and fluorescent as the primary source of lighting in the municipal buildings. By switching these out with LED lights, they would recognize consistent annual savings, both in energy usage and replacement costs. As shown in TABLE BELOW, the lifespan of an LED is approximately 20,000 hours, about twice as long as a fluorescent light and about ten times longer than an incandescent light. A 20,000-hour lifespan is approximately 7 years, assuming 8 years of usage per day. In addition, LED lights can provide the same amount of luminescence (brightness) than either incandescent or fluorescents while operating at a much lower wattage. This means LED's can also save money on monthly utility costs.

If we look at the table below at the 20,000 hours (LED lifespan) as a whole, we will see that by the time we replace one LED light, we would have replaced 2 fluorescents and 10 incandescent. Although the LED light is more expensive per unit ($10 compared to $8 or $3), only having to replace it once every 20,000 hours means LEDs actually have a lower unit cost than either fluorescents or incandescent in the long run. In addition, based on the $0.09/kWh pricing assumption, we see that the lower wattage of LED lights provides a significantly cheaper utility cost at the end of 20,000 hours as compared to their fluorescent or incandescent counterparts. Combining the replacement costs with utility costs, it appears that LED light bulbs cost an average of $24.00 per bulb every 20,000 hours, less than the $46 cost of fluorescents and much less than the $150 cost of incandescent.

Furthermore, the installation of motion sensors could help to regulate these lights based on activity in the rooms. The Green Age found they were able to install motion sensors at approximately $30 apiece. For each incandescent light bulb that gets swapped out for an LED light, the savings of $126 per unit is enough to buy 4 motion sensors, more than enough to cover a few rooms. These motion sensors, by regulating the LED activity, will further help cut down on utility costs by furthering the lifespan of these lights.

Type of Light	Wattage (60 watts equivalent)	Lifespan (hours)	Cost per bulb (dollars)	kWh usage (20000 hr. equivalent)	Cost of electricity ($0.10 cents/kWh)	Bulbs needed for 20,000 hours	Replacement cost after 20,000 hours	Total cost every 20,000 hours
LED	7	20000	$10.00	140	$14.00	1	$10.00	$24.00

Incandescent	60	2000	$3.00	1200	$120.00	10	$30.00	$150.00
Fluorescent	15	10000	$8.00	300	$30.00	2	$16.00	$46.00

We chose this as our second recommendation because it has slightly higher capital costs than insulating windows around the building. However, transitioning to LED lights and motion sensors is not necessarily a physically laborious effort, so implementation is still easy. Initial purchase price of LEDs and motion sensors may be the biggest impediment to making this change, but as found above, they pay for themselves over time and initial purchase price is likely to decline as technological innovators continue to improve LEDs.

Recommendation #3: Hi-R Retrofitted Window Panels

Our third recommendation would be to fully replace the single pane windows in the buildings. This recommendation is of lower priority given the higher cost and therefore decreased likelihood of immediate implementation. While the plastic insulation kits would increase R-values of 30-year-old windows, modern double or triple pane windows would see the R-value increase by 400-600 percent over the current single pane windows in use (Craven, 2011). The Planning and Building building and the Service and Engineering buildings are particularly good candidates, given the prevalence of single pane windows. City Hall was also noted for the leaks that have been plugged around the frame, as this is a similar short-term fix to the plastic mentioned above. The Community Center and Fire Station have double pane windows, and as such were not considered as high of a priority. However, as the Community Center replaces sections of their roofing they are also replacing windows, and the fire station may consider a similar approach if they replace their roof in 2018 as planned.

Rather than entirely replacing windows in the buildings, Worthington may consider a retrofitting of the existing windows. The GSA federal building in Provo, Utah retrofitted 21 single pane windows with triple pane Hi-R panels. These panels are installed on the inside of the window and are a much less costly and time intensive process than entirely replacing the windows. The GSA estimated the cost of the retrofitting to cost $32.40 per square foot of glass. While this is a higher cost than the window insulation kits, it would also see R-values more than quadruple (GSA, 2013). Given the amount of single pane windows in both Service and Engineering and Planning and Building buildings, this would be an upgrade we suggest in the near future when the budget is more flexible. City Hall would also certainly benefit from this retrofitting given the size of their window fixtures, and it would not hinder the aesthetics of the building. The Community Center and fire department are the most likely to upgrade their windows in the near future when they begin roofing renovations. While installing new windows in conjunction with fixing the roof is a large upfront cost, it is also going to produce the best results in energy savings. Though given that these two buildings already have double pane windows these should be the last two buildings considered for upgrades other than those necessary with roofing.

To evaluate the implementation of these Hi-R retrofit panels the same formula provided by Boschetti, and used in Recommendation #1, was employed. In evaluating the window retrofits, their energy savings were compared to the same figures found for single-pane windows in Recommendation #1. Once again, the energy loss per square foot of single-pane glass per year was calculated to be $2.99. Given that these window retrofits would increase the single-pane windows R-value to that of a triple-pane window, an R-value of 7 was used in these calculations. Thus the energy loss per square foot per year after installing these retrofits came to 14,360.64 BTU. The energy loss given this new figure came to just $0.38 per square foot of glass. This represents a savings of $2.61/square foot/year. With an installation cost of $32.40 cited in the GSA study, the payoff period/square foot of glass comes to 12.2 years.

Given that these window retrofits are a much longer-term investment; a calculation of net present value was performed. This evaluation of net present value was conducted using a discount rate of five percent, an annual energy rate increase of three percent, and a 20-year lifespan. The calculation came to a NPV value of $7.73, per square foot of glass. While this may seem like a small amount, it equates to a $115.95 value for one 3'x5' window, if the retrofits last only 20 years. While it is certainly a larger financial commitment than the plastic window insulation kits, it would be a one-time installation by an outside professional, while also improving the aesthetics of the building.

Recommendation #4: Upgrade/Replace Older HVAC Systems

Our fourth recommendation, upgrading and replacing existing HVAC (heating, ventilation, air conditioning) systems, is one that will be a major contributor to energy savings, but will involve significant upfront capital and cannot be implemented as easily as the previous recommendations. A high-efficiency HVAC system can serve a multitude of benefits in both qualitative and quantitative measures. High-efficiency HVACs provide increased climate control, sometimes by use of automatic and programmable thermostats. They also have a much longer lifespan than their older counterparts. These high-efficiency HVACs also consume less energy and therefore have a smaller environmental impact. In addition, they can also provide significant monthly savings on utility bills. Energy Star approved appliances have been shown to save upwards of 20% on heating and cooling costs by making the switch (Energy Star 2016).

Of note should be that a typical HVAC system does not have a lifespan of much longer than 15-20 years. As we were completing our walkthroughs, it was brought to our attention that the HVAC systems in most of the buildings had outlived their projected lifespan. In particular, the Building & Planning and Service & Engineering buildings, as well as City Hall, all had HVAC systems that had been in operation since the 1980s, well past the 15-20 year suggested lifespan. In fact, some of these systems are now so old that the process of finding replacement parts can range from somewhat challenging to downright impossible. We understand the City of Worthington is working on a budget, and that the cost of a high-efficiency HVAC system can be thousands of dollars, plus significant labor costs. For this reason, we suggest that the City of Worthington postpone upgrading until the HVAC system is no longer functioning, or there is ample room in the budget for such a large project to be implemented in multiple buildings. However, when the transition is finally made, we recommend the high-efficiency systems due to the increased energy savings that will be realized each month.

As discussed, the replacement of HVAC units is unlikely to take place before the current units fail. When these replacements do become essential, it is our suggestion that

Worthington purchase the Energy Star certified Rheem 5 Ton 15 SEER R410A X-13 Complete Split System Heat Pump. This unit would provide heating and air conditioning for approximately 3000 square feet, supplied entirely by electricity. Given the wide variety of HVAC units currently in use by Worthington, comparing this unit to the current ones is unrealistic. However, energystar.gov states that an Energy Star certified unit can save the user 20 percent on energy bills compared to a baseline, non-certified model. Given that energy.gov suggests that heating and cooling costs account for 48 percent of energy expenditure, this would mean a 9.6 percent savings annually compared to baseline models. To provide a real example of the benefits, City Hall was analyzed. Given the City Hall building is 12,032 square feet it would require four of the HVAC units suggested, each costing $4,000 for a total investment of $16,000 if they were all replaced at once. In the past 12 months, City Hall has spent $13,429.32 on electricity alone. Thus the amount spent on heating and cooling, given the energy.gov estimates, is $6,446.07. If a new HVAC unit reduced this amount by 20 percent, the annual savings would be $1,289.21. Thus the payback period for installing four new HVAC systems would be 12.4 years.

Evaluating the above discussion further, an NPV analysis was performed for the HVAC units. Using a discount rate of five percent, annual electricity price increases of three percent, and a twenty-year lifespan, the NPV was calculated to be $3,875.83. While the initial investment of $16,000 seems high for present value benefits of less than 25 percent of investment, these calculations were performed assuming that City Hall currently employs four 2016 HVAC units. Given the knowledge that many of their HVAC units are older than 15 years, their current HVACs are certainly less efficient than a baseline 2016 model. Thus the savings found would represent the savings of choosing an Energy Star approved model, rather than a standard new model, which would still cost around $2,000.

Recommendation #5: Rooftop Renovations (When Replacement is Warranted)

Finally, our group recommends rooftop renovations, specifically for the community center and fire department. Similar to the HVAC recommendation, rooftop renovations can be very costly in terms of both time and money. Given Worthington's tight budget, this is our lowest priority recommendation. However, during the walkthroughs we learned that the rooftops on the community center and fire department were showing signs of aging, and discussions have already started regarding rooftop renovations. Given the variety of roofing options, it would serve Worthington best to evaluate all options for installation cost and payback period based on energy savings. Our group recommends that as an initial step the city buildings ensure the internal insulation of the roofing is completed, given that this is a lower initial cost and is an integral part of an energy efficient roof. When roofing is replaced we recommend installing a 'cool roof' system, which reflects more heat than a standard roof. The innovations in this area are constantly developing and should be evaluated the year they decide to replace the roofing rather than several years ahead. Using the Oak Ridge National Laboratory roof savings calculator, Worthington will be able to generate safe estimates of how much energy each type of roofing will save them. The calculator takes into account the building location, age, current roofing, HVAC efficiency, and energy costs, which will allow Worthington to accurately assess their best roofing option for payback period (ORNL 2016). Given that cool roofing can reduce roof surface temperatures by 50 degrees Fahrenheit according to Energy Star, installing one together with good insulation would decrease the cooling costs substantially in the summer (Energy Star 2016).

Conclusions

Our energy savings recommendations provide the City of Worthington with an initial plan in reducing energy costs. Nonetheless, we believe that our general recommendations will yield significant energy savings and positive net present value of costs, making them very attractive for the city. With the energy savings the city incurs, greater funds will be available for each department to improve their respective services to the community of Worthington. By tackling the “low hanging fruit” suggestions, the city will be able to reap the net cost savings of these changes quickly and provide a solid basis for future investments in the energy reduction practices outlined in this report. Implementing plastic insulation for the cities building has been proved to pay for itself in a short time period and is relatively inexpensive and easy to install. LED lighting fixtures are slightly more expensive to install but also end up with a relatively short payback period, as they are much more energy efficient and have a longer life span than most of the current lights in the buildings our team evaluated. Although the city of Worthington is budget constrained, at the moment, this report offers options that can be implemented whenever the necessary funds become available. Once the least expensive options are implemented, and energy savings are realized, they will help validate the implementation of the costlier suggestions. Also the continuing cost savings from the initial recommendations could be utilized in the budgets of each of the buildings and allow for other, more capital intensive, improvements to be made.

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APPENDIX

A. FIGURES

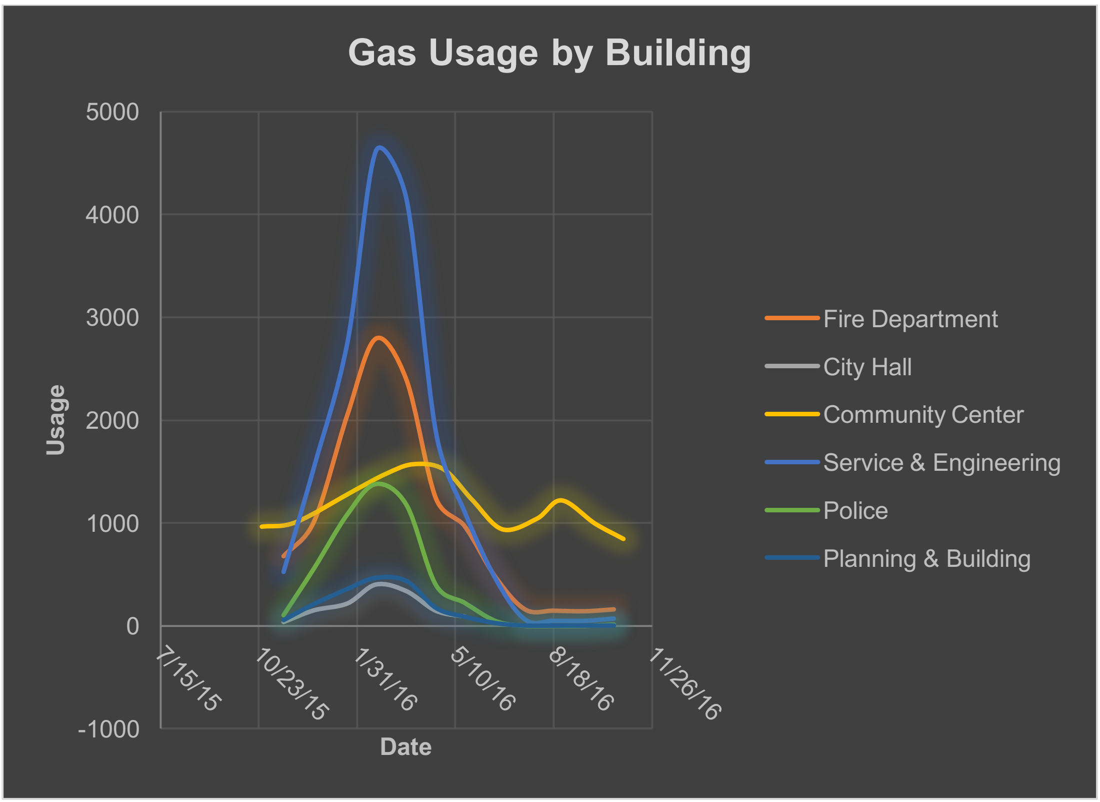


Figure 1

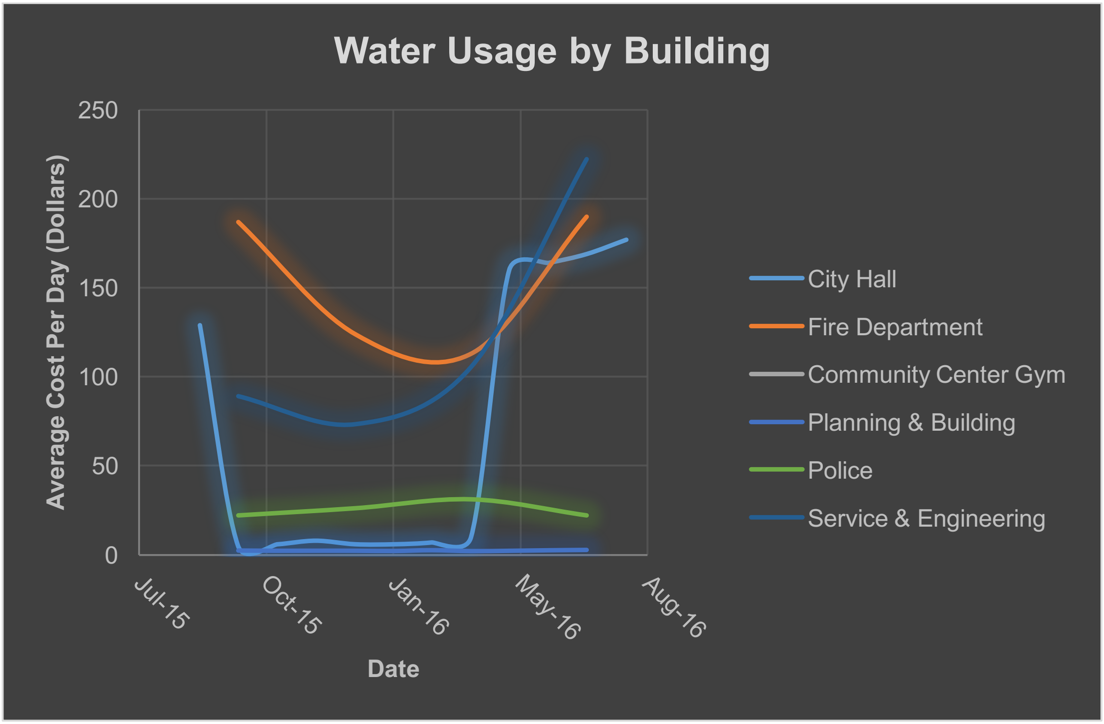


Figure 2

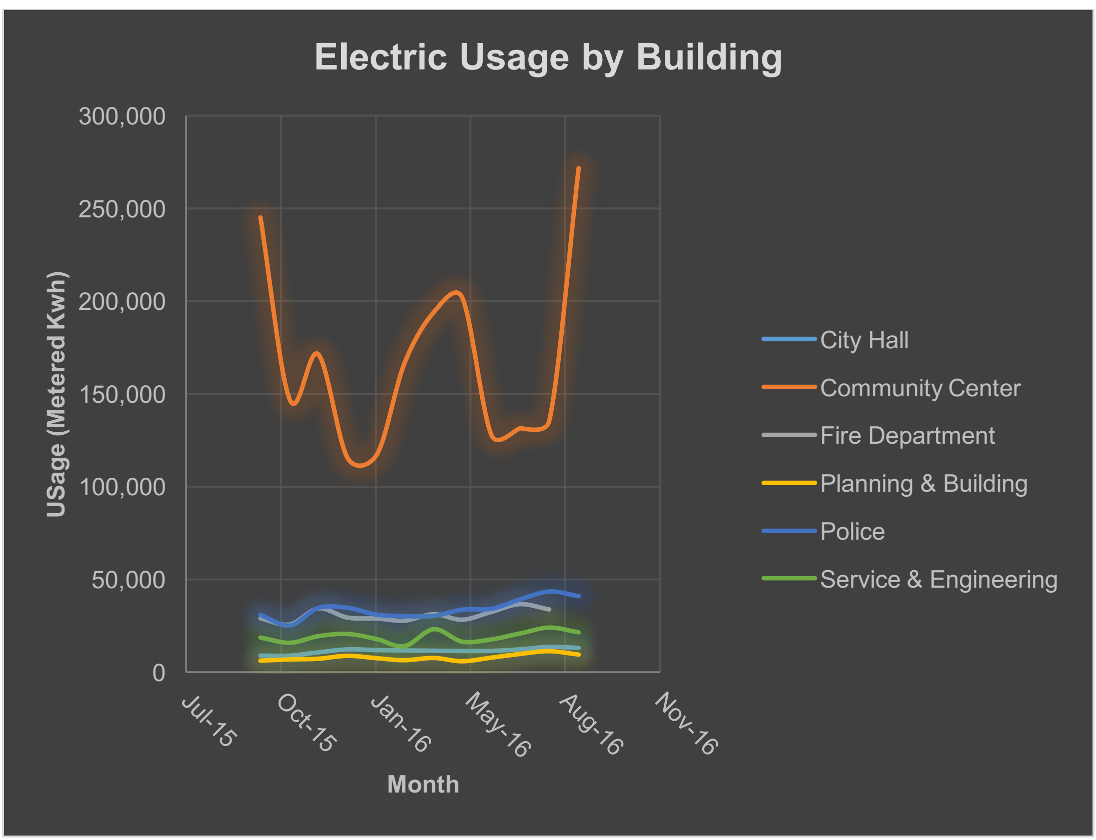


Figure 3

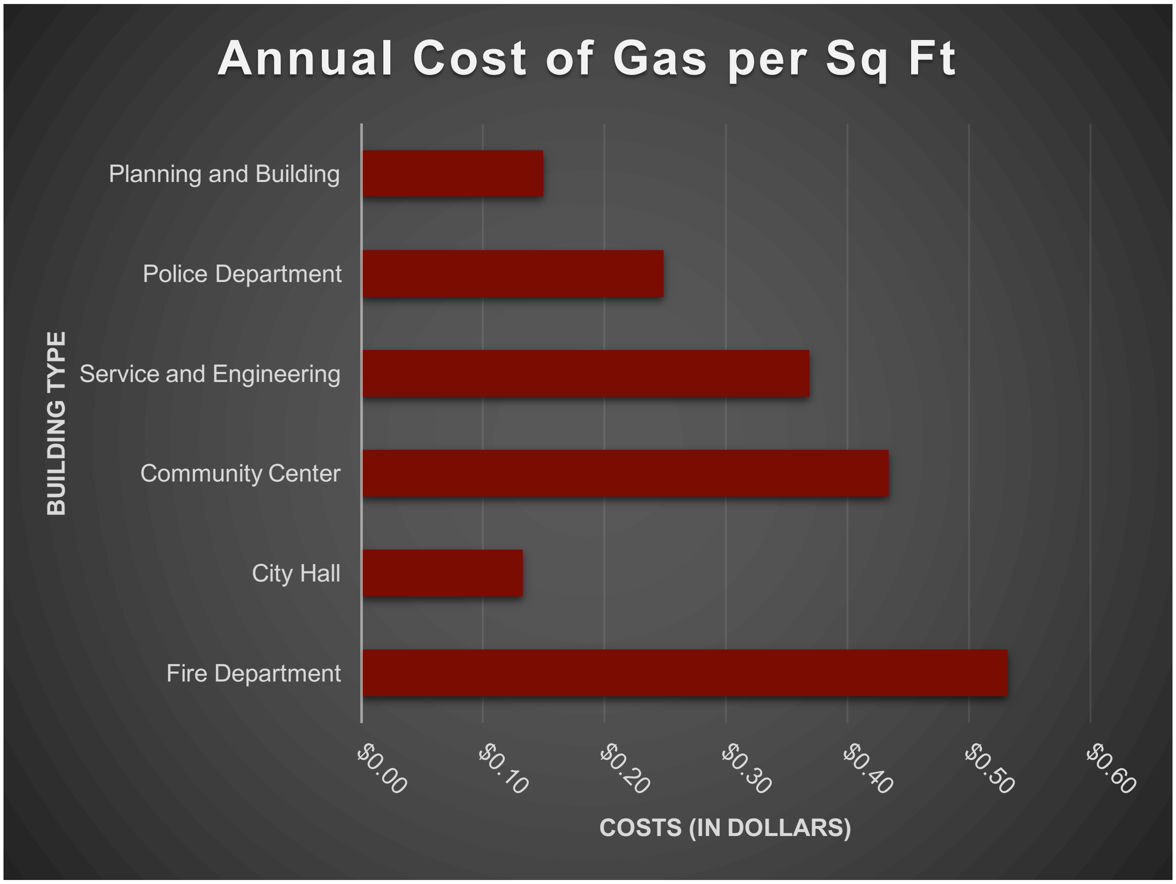
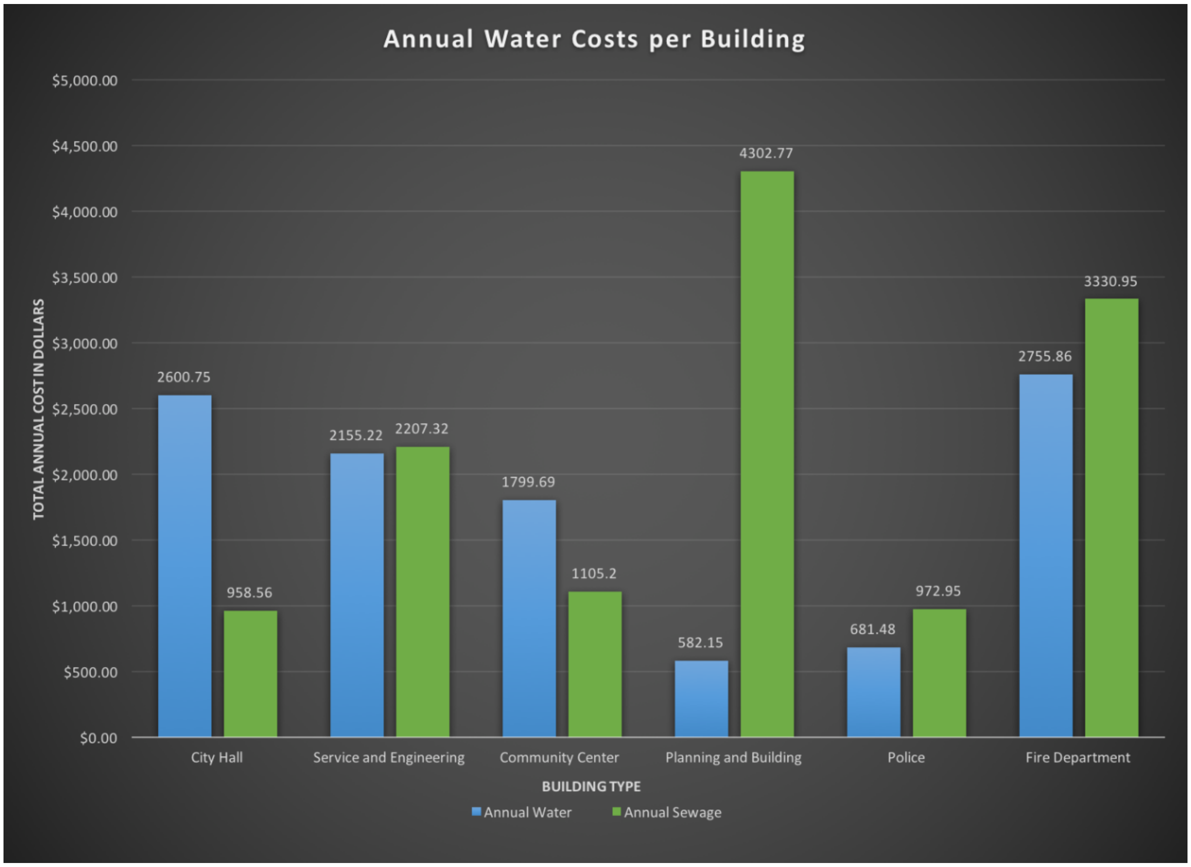

Annual Cost of Gas per Sq Ft
Planning and Building
Police Department
Service and Engineering
Community Center
City Hall
Fire Department
BUILDING TYPE
$0.00
$0.10
$0.20
$0.30
$0.40
$0.50
$0.60
COSTS (IN DOLLARS)

Figure 4



Annual Water Costs per Building
TOTAL ANNUAL COST IN DOLLARS
$5,000.00
$4,500.00
$4,000.00
$3,500.00
$3,000.00
$2,500.00
$2,000.00
$1,500.00
$1,000.00
$500.00
$0.00
2600.75
958.56
2155.22
2207.32
1799.69
1105.2
582.15
4302.77
681.48
972.95
2755.86
3330.95
City Hall
Service and Engineering
Community Center
Planning and Building
Police
Fire Department
BUILDING TYPE
Annual Water
Annual Sewage

Figure 5

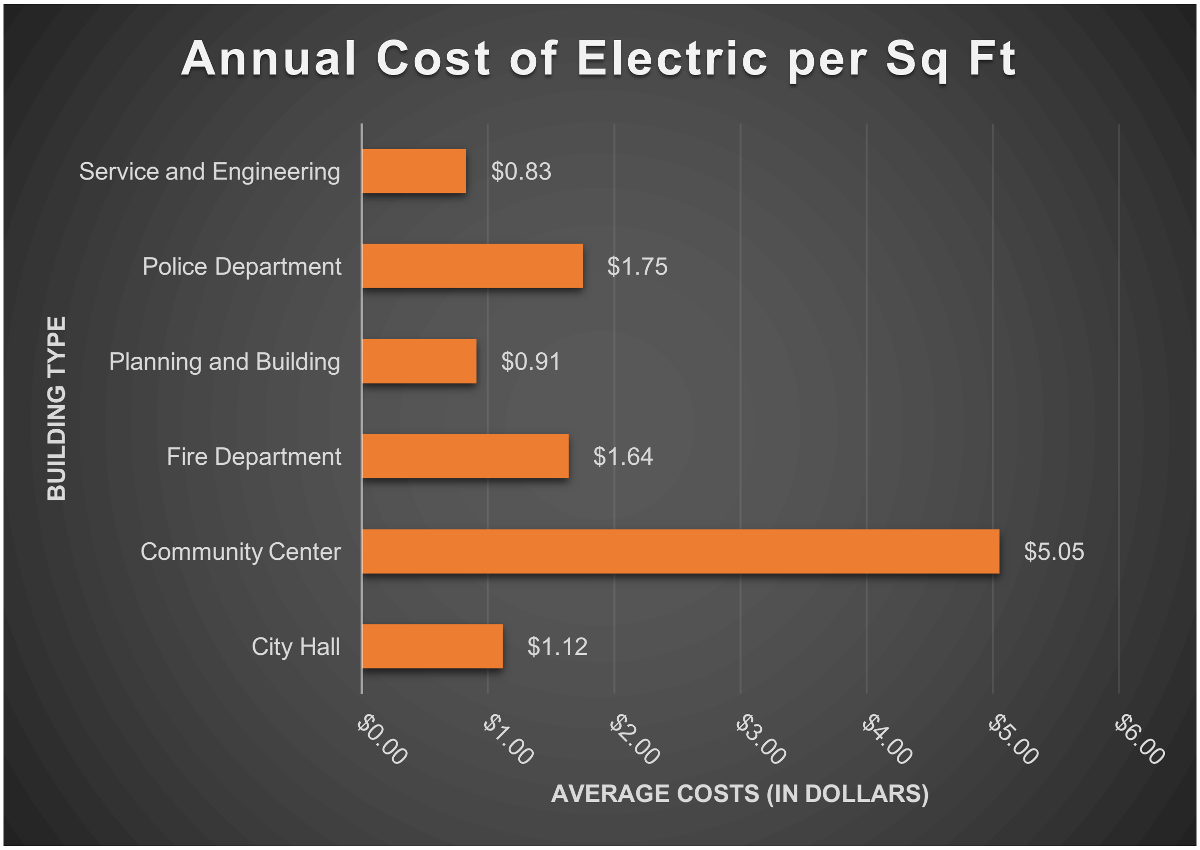

Annual Cost of Electric per Sq Ft
BUILDING TYPE
Service and Engineering
Police Department
Planning and Building
Fire Department
Community Center
City Hall
$0.83
$1.75
$0.91
$1.64
$5.05
$1.12
$0.00
$1.00
$2.00
$3.00
$4.00
$5.00
$6.00
AVERAGE COSTS (IN DOLLARS)

Figure 6